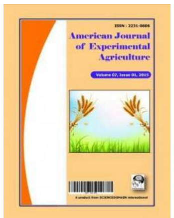

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Effect of Integrated Nutrient Management on Yield and Yield Attributes of Sweet Corn (*Zea mays* L. *saccharata*) Under Wet Temperate Conditions of Western Himalayas (India)

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Authors' contributions

This research work was carried out in collaboration between all authors. Authors SR and RHK designed the study, wrote the protocol and wrote the first draft of the manuscript. Author BAA reviewed the experimental design and all drafts of the manuscript. Authors SR and SH managed the analysis of the experiment. Authors ZAD and WR performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

A field study was carried out in Experimental Farm of Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, J&K, India during *kharif* 2011 and 2012 to study the influence of integrated nutrient management on yield and

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yield attributes of sweet corn var. Super-75. The results revealed that yield contributing characters viz., cob length and diameter with and without husk, number of cobs per plant, rows per cob, grains per row and weight of cob with and without husk were significantly higher with application of 75% (NPK) + Farmyard manure (FYM) (4.5 t ha^{-1}) + biofertilizer (*Azotobacter* + Phosphate solubilizing bacteria (PSB) over unfertilized control and other treatments. This treatment also proved to be significantly superior to rest of the treatments including unfertilized control in increasing cob yield with and without husk, fodder yield and green biomass yield during both years of experimentation. The ratio of cob to fodder yield during 2011 was recorded highest in treatment FYM (18 t ha^{-1}), while during 2012, NPK (90:60:40 kg ha^{-1}) recorded the highest ratio of cob to fodder yield.

Keywords: Sweet maize; organic fertilizer; inorganic fertilizers; growth; yield.

1. INTRODUCTION

Sweet corn (*Zea mays* L. *saccharata*) also known as sugar corn is a hybridized variety of maize (*Zea mays* L.) specifically bred to increase the sugar content. Sweet corn is introduced to India from USA. It has a sugary rather than a starchy endosperm and a creamy texture. The low starch level makes the kernel wrinkled rather than plumpy. At harvest, an optimum kernel moisture content of 70 to 74 per cent is required to achieve acceptable frozen cobs [1]. When the moisture content is higher than 74 per cent the cobs are immature and below 70 per cent they loose the sweetness and develop an unpleasant taste and texture. It has a thinner pericarp than the normal corn making it tender [2]. The green cobs are eaten, roasted or boiled. In sweet corn best nutritional quality depends on moisture (72.7%) and total solids (22.3%) comprising of carbohydrate (81%), protein (13%) and lipids (3.5%).

Among the various factors affecting the growth and yield of sweet corn, nutrient management plays a vital role. It is desired that the soil should have the required nutrients in sufficient quantities and in optimum proportion to meet the requirement of crop. Presently, the chemical fertilizers are considered as the major source of nutrients. However, the escalating cost, coupled with increasing demand of chemical fertilizers and depleting soil health necessitates the safe and efficient use of organics in crop production. Apart from this, the concept of organic farming which excludes the use of chemical fertilizers and pesticides from the perspective of eco-friendly management, organic agriculture has many advantages over conventional agriculture. We can no longer afford to ignore the need to actively manage ecological services focusing on farming as indicated in the "Millennium Ecosystem Assessment Report." A recent study by [3], at Rodale Institute on organic farming over 22 years, showed greater advantages of animal based organic system than conventional system. However, under arable production system organic manures suffers from the drawback of slow release of nutrients at initial stages, may require 2-3 years required to sustain crop yields. To hasten the nutrient availability in organic production system through judicious combination of organic manures by tracing the positive aspects of green manures, crop residues, composts and liquid manures, in a more synchronized system can be developed to maintain long-term soil fertility and sustain higher productivity of crops. Hence, an integrated organic nutrient supply system provides an ideal nutrition for a crop to sustain yield levels and also enhance farm income.

In view of increasing awareness about sustainable agricultural system world wide, a new generation scientists are concentrating upon research in understanding the relationship between organics with components of soil like sustainable soil fertility, crop yield and protection of the environment. However, the change over from chemical to organic agriculture is difficult, as farmers have to forgo yields till the buildup of soil productivity to a desirable level. But, it is possible to effect a quick change over to sustainable agriculture by harnessing different integrated organic approaches mainly green manures, enriched compost, vermicompost, liquid manures, bio-fertilizers etc. Therefore, understanding of the influence of these nutrients is quite essential to exploit the field potentiality of the crop. In light of the above fact, the present study was undertaken with an objective to see the effect of integrated nutrient system on yield and its attributes in sweet corn.

2. MATERIALS AND METHODS

A field experiment was conducted for two consecutive years (*kharif* 2011 and 2012) at the Experimental Farm of the Division of Agronomy, Sher-e-Kashmir University of Agricultural

Sciences and Technology of Kashmir that lies between 34°0.8' N latitude and 74°83' E longitude at an altitude of 1587 meters above mean sea level. The experimental site was well drained and had uniform topography. The experiment comprising of 12 treatments viz., T_1 = Control, T_2 = Recommended NPK kg ha^{-1} (90:60:40), T_3 = Farm yard manure (FYM) (18 t ha^{-1}), T_4 = Vermicompost (3.6 t ha^{-1}), T_5 = Biofertilizer (*Azotobacter* + Phosphate solubilizing bacteria (PSB), T_6 = 75% (NPK) + FYM (4.5 t ha^{-1}), T_7 = 75% (NPK) + Vermicompost (0.9 t ha^{-1}), T_8 = 75% (NPK) + Biofertilizer, T_9 = 75% (NPK) + FYM (2.25 t ha^{-1}) + Vermicompost (0.45 t ha^{-1}), T_{10} = 75% (NPK) + FYM (4.5 t/ha) + Biofertilizer (*Azotobacter* + PSB), T_{11} = 75% (NPK) + Vermicompost (0.9 t/ha) + Biofertilizer (*Azotobacter* + PSB) and T_{12} = 75% (NPK) + FYM (2.25 t/ha) + Vermicompost (0.45 t/ha) + Biofertilizer (*Azotobacter* + PSB)] was laid in a Randomized Block Design with three replications. Sweet corn variety Super-75 was used as an experimental material.

The soil of experimental field was silty clay loam in texture, neutral in reaction and medium in available nitrogen, phosphorus and potassium. The chemical fertilizers Urea, DAP and MOP were used as source of nitrogen, phosphorus and potassium, respectively. Full dose of phosphorus and potassium and half dose of nitrogen were applied as basal at the time of sowing and the remaining half of nitrogen in two splits each at knee high and tassel emergence stage in the respective plots at the rates as per layout plan. Farmyard manure (FYM) and vermicompost were used as source of nitrogen, phosphorus, potassium and micro-elements in the form of organic manure and were applied to the respective plots as per the layout plan. The microbial culture of *Azotobacter* and Phosphorus solbulizing bacteria (PSB) were used as bio-fertilizers as a seed treatment (50 g kg^{-1} seed) to the respective plots. The field was irrigated twice from sowing to the harvest of cobs.

The data were recorded on cob length with and without husk (cm), cob diameter with and without husk (cm), number of cobs $plant^{-1}$, number of grain rows cob^{-1}, number of grains row^{-1} and weight of green cob (g) from 5 cobs taken randomly from each net plot. Green cob yield with and without husk (q ha^{-1}), green fodder yield (q ha^{-1}) and biomass yield (q ha^{-1}) plot were harvested and recorded separately as q $plot^{-1}$ and then converted in q ha^{-1}. The ratio of cob to fodder yield was determined by dividing the cob yield with husk by fodder yield per plot. The data obtained in respect of various observations were statistically analyzed by the method described by [4]. The significance of "F" and "t" was tested at 5% level of significance. The critical difference was determined when "F" test was significant.

3. RESULTS

3.1 Yield Contributing Characters

3.1.1 Length of cob with and without husk (cm)

Data presented in Table 1 makes it evident that the length of cob with and without husk varied significantly amongst treatments. The treatment T_{10} was at par with T_{11} and T_{12} recorded significantly higher cob lengths with husk i.e., 26.05, 26.34 and 26.20 cm and without husk i.e., 22.21 and 22.53 cm during 2011 and 2012, respectively compared to other treatments. Significantly lowest cob length with and without husk was recorded under unfertilized treatment during both years of experimentation.

3.1.2 Diameter of cob with and without husk (cm)

Diameter of cob showed marked variation amongst the treatments. The treatment T_{10} recorded significantly highest cob diameter with husk i.e., 6.01 and 6.08 cm and without husk i.e., 4.92 and 4.98 cm during 2011 and 2012. The treatment T_9 though recorded significantly lower cob diameter with husk than T_{10} was the second highest treatment being at par with T_7, T_{11} and T_{12} was significantly superior to rest of the treatments (Table 1). As regards cob diameter without husk the treatment T_{12} was second highest treatment being at par with T_{11} but significantly superior to rest of the treatments. It was also noted that unfertilized control recorded significantly lowest cob diameter with and without husk during both years of investigation.

3.1.3 Number of cobs per plant

Number of cobs $plant^{-1}$ has a direct bearing on yield of the crop. The data with respect to cobs $plant^{-1}$ is presented in (Table1) indicated that treatment T_{10} significantly increased the number of cobs $plant^{-1}$ over T_1, T_2 and T_8 though being at par with rest of the treatments during 2011 and 2012. The magnitude of increase in cobs $plant^{-1}$ recorded with T_{10} over T_1 was to the tune of 70.0 and 75.0 per cent during 2011 and 2012.

Table 1. Effect of integrated nutrient management on yield attributes of sweet corn

Treatments	Length of cob with husk (cm)		Length of cob without husk (cm)		Diameter of cob with husk (cm)		Diameter of cob without husk (cm)		Cobs plant^{-1}		No. of grains row^{-1}		No. of rows cob^{-1}	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
T1	19.95	19.27	17.16	16.78	3.76	3.70	3.07	3.02	1.00	1.00	29.25	28.31	13.30	13.20
T2	24.04	24.33	20.22	20.52	5.47	5.56	4.14	4.18	1.32	1.40	34.16	34.95	16.40	16.50
T3	22.13	24.22	18.34	20.43	4.82	5.32	3.90	4.10	1.50	1.60	31.22	33.16	14.40	15.90
T4	22.53	23.65	18.76	19.82	5.31	5.47	4.07	4.15	1.45	1.50	32.37	34.32	15.10	15.90
T5	23.00	24.12	19.21	20.33	4.80	4.98	3.95	4.00	1.30	1.35	32.94	34.87	15.60	16.00
T6	23.83	24.59	20.03	20.82	5.57	5.65	4.17	4.21	1.50	1.55	33.19	35.41	15.20	16.10
T7	24.11	24.54	20.32	20.75	5.61	5.69	4.23	4.27	1.45	1.45	34.33	35.11	15.80	16.10
T8	24.69	24.88	20.86	21.10	5.09	5.25	4.11	4.18	1.30	1.40	35.00	36.12	15.90	16.30
T9	24.81	25.11	21.02	21.32	5.80	5.89	4.33	4.38	1.40	1.50	34.27	37.28	16.10	16.40
T10	26.05	26.34	22.21	22.53	6.01	6.08	4.92	4.98	1.70	1.75	36.22	37.85	16.60	16.90
T11	25.11	25.71	21.32	21.92	5.71	5.79	4.62	4.73	1.50	1.60	35.39	36.72	15.90	16.50
T12	25.32	25.84	21.51	22.05	5.79	5.86	4.75	4.80	1.55	1.65	35.67	36.96	16.20	16.50
SEM±	0.383	0.412	0.360	0.365	0.064	0.064	0.049	0.050	0.085	0.087	0.345	0.384	0.181	0.203
CD (p≤0.05)	1.13	1.22	1.06	1.07	0.188	0.190	0.144	0.149	0.249	0.257	1.07	1.19	0.56	0.63

3.1.4 Number of grains per row

Number of grains row^{-1} showed that the treatment T_{10} being at par with T_{11} and T_{12} significantly improved number of grains row^{-1} over rest of the treatments during two years of investigation. Significantly lowest number of grains row^{-1} were recorded under unfertilized treatment (Table 1).

3.1.5 Number of rows per cob

The data pertaining to number of rows cob^{-1} exhibited that the treatment T_{10} at par with T_2, T_9, T_{11} and T_{12} was significantly superior over rest of the treatments during 2011 and 2012 (Table 1).

The unfertilized control recorded significantly lowest number of rows cob^{-1} compared to other treatments during both years of investigation.

3.1.6 Weight of green cob with and without husk (g)

It was observed that significantly highest green cob weight with and without husk was recorded under treatment T_{10} (Table 2). As regards weight of green cob with husk it was found that T_{10} remained at par with T_2 but significantly increased weight of green cob with husk over rest of the treatments and the magnitude of increase over unfertilized treatment was to the tune of 22.14 and 31.40 per cent during 2011 and 2012, respectively. As regards weight of green cob without husk it was noticed that T_{10} being at par with T_2 and T_{12} significantly increased the weight of green cobs over rest of the treatments and the magnitude of increase recorded by the treatment over unfertilized control was to the tune of 17.56 and 26.65 per cent during 2011 and 2012, respectively.

3.2 Yield

3.2.1 Cob yield with and without husk (q ha^{-1})

Yield is the final criterion to judge the efficiency of the treatment. The perusal of the Table 3 revealed that the treatment T_{10} proved to be significantly superior to rest of the treatments including unfertilized control in increasing the cob yield with and without husk during both years of experimentation. The treatment T_{12} was the next best treatment to improve cob yield as compared to other treatments, however without husk it remained at par with T_{11}. The yield superiority of T_{10} over unfertilized control with regard to cob yield with husk was to the tune of 107.64 and 129.96 per cent and with regard to cob yield without husk the increase in yield was to the tune of 99.86 and 121.63 per cent during 2011 and 2012, respectively.

3.2.2 Fodder yield (q ha^{-1})

The treatment T_{10} recorded significantly higher yield compared to rest of the treatments and the yield superiority recorded over unfertilized control was to the tune of 115.98 and 124.78 per cent during 2011 and 2012 and, respectively (Table 3). It was also observed that the treatment T_{12} being the next best treatment was at par with T_3, T_{12} and T_2 but significantly superior to rest of the treatments during the period of study.

Table 2. Effect of integrated nutrient management on weight of green cob with and without (g) of sweet corn

Treatments	Weight of green cob with husk (g)		Weight of green cob without husk (g)	
	2011	2012	2011	2012
T1	223.60	216.02	168.51	162.11
T2	265.03	272.92	191.03	196.92
T3	222.12	262.87	165.12	190.87
T4	240.11	257.21	176.11	187.21
T5	216.36	223.65	163.36	170.72
T6	247.23	254.26	180.23	184.79
T7	254.31	259.13	184.31	188.32
T8	257.42	265.16	187.42	192.51
T9	261.32	268.41	190.32	195.86
T10	273.11	283.86	198.11	205.31
T11	255.76	267.80	187.76	195.76
T12	259.92	269.93	190.92	197.93
SEM±	3.390	4.728	2.645	2.781
CD (p≤0.05)	10.01	13.96	7.81	8.21

Table 3. Effect of integrated nutrient management on yield of sweet corn

Treatments	Cob yield with husk (q ha^{-1})		Cob yield without husk (q ha^{-1})		Fodder yield (q ha^{-1})		Green biomass yield (q ha^{-1})		Ratio of cob to fodder yield	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
T1	167.42	161.74	126.17	121.38	187.98	182.52	355.40	344.26	1:1.12	1:1.13
T2	261.94	286.08	188.80	206.42	367.70	378.09	629.64	664.17	1:1.40	1:1.32
T3	249.47	314.91	185.45	228.66	374.87	389.69	624.34	704.60	1:1.50	1:1.24
T4	260.68	288.88	191.20	210.26	354.03	363.65	614.71	652.53	1:1.36	1:1.26
T5	210.60	226.07	159.01	172.56	273.53	295.45	484.13	521.52	1:1.30	1:1.31
T6	277.67	295.08	202.42	214.46	351.40	357.79	629.07	652.87	1:1.27	1:1.21
T7	276.10	281.33	200.10	204.45	358.46	354.15	634.56	635.48	1:1.30	1:1.26
T8	250.56	277.95	182.43	201.80	339.75	357.02	590.31	634.97	1:1.36	1:1.28
T9	273.93	301.45	199.50	219.97	382.05	390.98	655.98	692.43	1:1.39	1:1.30
T10	347.63	371.94	252.17	269.02	406.01	410.27	753.64	782.21	1:1.17	1:1.10
T11	287.25	320.82	210.88	234.52	387.99	390.96	675.24	711.78	1:1.35	1:1.22
T12	301.65	333.48	221.57	244.53	388.65	391.76	690.30	725.24	1:1.29	1:1.17
SEM±	3.187	3.455	3.766	4.075	5.179	5.259	12.281	13.924	-	-
CD (p≤0.05)	9.41	10.20	11.12	12.03	15.29	15.52	36.26	41.11	-	-

3.2.3 Green biomass yield (q ha^{-1})

It was observed that green biomass yield varied significantly under the influence of different treatments and followed a similar trend as that of yield (Table 3). The treatment T_{10} recorded significantly highest green biomass yield compared to other treatments during both years of investigation and pooled data over years. T_{12} was the next best treatment with regard to increase in green biomass yield over other treatments except that it was at par with T_{11}. Significantly lowest green biomass yield was recorded with unfertilized control.

3.2.4 Ratio of cob to fodder yield

Data presented in Table 3 revealed that there was no definite trend amongst different treatments with regard to ratio of cob to fodder yield. During 2011 the treatment T_3 recorded the highest cob to fodder ratio of 1:1.50 which was closely followed by T_2 with the ratio of 1:1.40, whereas during 2012 T_2 recorded the highest cob to fodder ratio of 1:1.32 which was closely followed by T_5 with ratio of 1:1.31 and T_{12} with ratio of 1:1.30. Among the 12 treatments the lowest ratio of cob to fodder yield was observed in unfertilized control during both years of study.

4. DISCUSSION

Sweet corn being a C4 plant is very efficient in converting solar energy into dry matter. As heavy feeder of nutrients, its productivity is largely dependent on nutrient management. Therefore, it needs fertile soil to express its yield potential. Soil fertility deterioration is due to continuous use of chemical fertilizers has been major bar to sustain crop productivity. Under such conditions an integrated approach is suggested through complementary use of inorganic and organic fertilizers to boost soil fertility and crop productivity [5]. Organic manures not only supply the plant nutrients but also improve soil health. Moreover, the amount of micronutrients present in organic manures may be sufficient to meet the requirement of crop production [6]. Therefore, integrated nutrient management (INM) is an option as it utilizes available organic and inorganic nutrients to build ecologically sound and economically viable farming system. Intensive cultivation, growing of exhaustive crops, use of unbalanced and inadequate fertilizers accompanied by restricted use of organic manures have made the soils not only deficient in the nutrients, but also deteriorated the soil health resulting in decline in crop response to recommended dose of N-fertilizer in the region under such situation, integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. Organic manures, particularly FYM and vermicompost, not only supply macronutrients but also meet the requirements of micronutrients, besides improving soil health [7-9]. To sustain the soil fertility and crop productivity the role of organic manures and fermented organic nutrients are very important. The organic fertilizers in addition to nutrients contain microbial load and growth promoting substances which helps in improving the plant growth, metabolic activity and resistance to pest and diseases. Boosting yield, reducing production cost and improving soil health are three inter-linked components of the sustainable triangle. Biofertilzers are low cost, environmentally safe and non bulky agricultural inputs as a supplementary and complementary factor to mineral nutrition [10]. Therefore, suitable combination of chemical fertilizer and organic manures cultures need to be developed for particular cropping system and soil.

The results of the present study indicated that application of T_{10} significantly increased cob length, cob diameter, weight of cob with and without husk, number of cobs plant^{-1}, grains cob^{-1} and number of rows cob^{-1}. These results are in conformity with the earlier findings of [11-15]. A faster growth CGR and RGR under the influence of NPK + FYM + biofertilizer might have played a significant role in reducing competition for photosynthates and nutrients with other plants resulting in healthy plants. The increased availability of photosynthates might have enhanced number of flowers and their fertilization resulting in higher number of filled cobs and grains cob^{-1}. Further, in most of the cereals, greater assimilating surface at reproductive developments resulted in better grain formation because of adequate production of metabolites and their translocation to grain. The increased NPK concentration and their uptake with better fertilization might have resulted in increased fresh weight of cob with and without husk. It appears that application of T_{10} not only supplied adequate amount of NPK but also might have played a major role (through FYM) in improving physico-chemical and biological properties of soil which might have resulted in the improvement of crop growth and finally enhancing yield attributes of the test crop. Besides, the marked improvement in the productivity of individual plant due to biofertilizer application might be due to its profound effect on dry matter production along with accumulation of nutrients. Thus, the greater availability of both these growth inputs might have maintained adequate supplies as per need of plant for yield impact on improving productivity of individual plant which could be ascribed to the fact that crop yield is a function of several yield attributing factors which are dependent on complementary interaction between vegetative and reproductive growth of the crop. The existence of favourable biofertilizer had a positive influence on both the phases of crop which ultimately led to realization of greater yield attributes.

4.1 Yield

Yield is a complex character, which is the product of multiplicative interactions of a number of its component characters, yield cannot be improved to a greater extent on its own. Hence, a clear picture of contribution of each component in final expression of complex character is essential. Significantly higher green cob yield with and without husk, green fodder and biomass yield of sweet corn were obtained with application of T_{10} during 2011 and 2012. Higher yields of sweet corn obtained with the application of integrated nutrients could be attributed to the readily available nitrogen and other nutrients in soil which have provided a suitable medium for enhanced growth of yield attributes viz., cob length, number of cobs per plant, number of grains per cob, length and diameter of cob etc. These results are similar to the findings of Afifi et al. [16] Kumar and Thakur [17], AICMIP [18,19] and Dadarwal et al. [14] who also observed significant increase in cob and fodder yield with combined application of organic and mineral fertilizers. In the present study, application of FYM and biofertilizer alongwith 75% NPK resulted in maximum yield that establishes the fact of synchrony between availability of nitrogen at critical stages of crop as well as other benefits derived from FYM. Application of organic manures plays a direct role in plant growth as a source of all the necessary major and minor nutrients in available forms during mineralization which improved both the physical and biological properties of the soil Abou El-Magd et al. [20], Dadarwal et al. [14]. Hence, it is clear that combined application of organic and inorganic nutrients plays a critical role in enhancing the productivity of sweet corn than individual application of these nutrients. Application of T_{10} also increased the fodder yield of the crop which could be attributed to significant improvement in plant height and dry matter accumulation of sweet corn. Earlier [21,22,13,23,24] also reported significant increase in fodder yield with integrated nutrient management system.

5. CONCLUSION

Results presented in this study indicated that for obtaining maximum cob and fodder yield in sweet corn, it needs to be fertilized with 75% (NPK) + FYM (4.5 t/ha) + Biofertilizer (*Azotobacter* + PSB). However, before giving final recommendations, the investigation needs to be carried out at different agro-climatic regions of the Valley to arrive at final conclusions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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